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ADVANCED TECHNOLOGY SATELLITES IN THE COMMERCIAL ENVIRONMENT

Volume 1: Executive Summary

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16. Abstract

It is now possible to place relatively large communications satellites in geostationary orbit, using the Shuttle. Other advanced technoloy, such as the use of 30/20 GHz (Ka) band has reached or is near the point of commercial use. The satellite industry, however, is in a state of transition from the early state with few operators, to a later state with many diverse operators and correspondingly many satellites. It is not clear if or how advanced technology will be incorporated into this enviroment.

This report postulates one set of scenarios, based on a set of traffic demand forecasts derived from previous contracts performed by Western Union and ITT. The scenarios use a demand-driven model to launch new satellites, with other limits on the available (and economical) technology. The results using a Low Traffic Forecast show a continuing oversupply of transponders. However, the scenarios using a High Traffic Forecast show that considerable advanced technology including the use of 30/20GHz will be needed to satisfy demand.

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EXECUTIVE SUMMARY

1.0 Task 1

The basic aim of Task 1 is to massage the forecasts provided by Western Union and ITT in order to obtain a forecast of transponder requirements including various factors. The WU and ITT forecasts are of satellite addressable traffic. This merely postulates the fraction of total traffic that is susceptible to satellite carriage. The end product of Task 1 purports to be a forecast of traffic that actually will be carried by satellite. Certain assumptions about system configurations are also implicit in this process.

The factors that we included in Task 1 are, in order: interpolation of the WU and ITT baseline year values to produce yearly figures; estimation of satellite capture; effects of peak-hours and the time-zone staggering of peak hours; circuit requirements for acceptable grade of service; capacity of satellite transponders, including various compression methods where applicable; and requirements for spare transponders in orbit. As part of Task 1, we also estimated the geographical distribution of traffic requirements.

These manipulations were applied to the basic forecasts to yield the gross, in-orbit transponder forecases shown in Figures 1 and 2.

Summary

Table 1 illustrates the effect that various processes in Task 1 have had on the base forecasts. We have illustrated this with the low traffic forecast for 1990. The basic satellite-addressable forecast is considered to be the normalized value of 1.0. The table shows the relative value after processing through the indicated stage. Thus, the combined effects of previous stages are included in these figures. In general, the capture fraction calculation had the most effect.

Figure 1

LOW TRAFFIC FORECAST

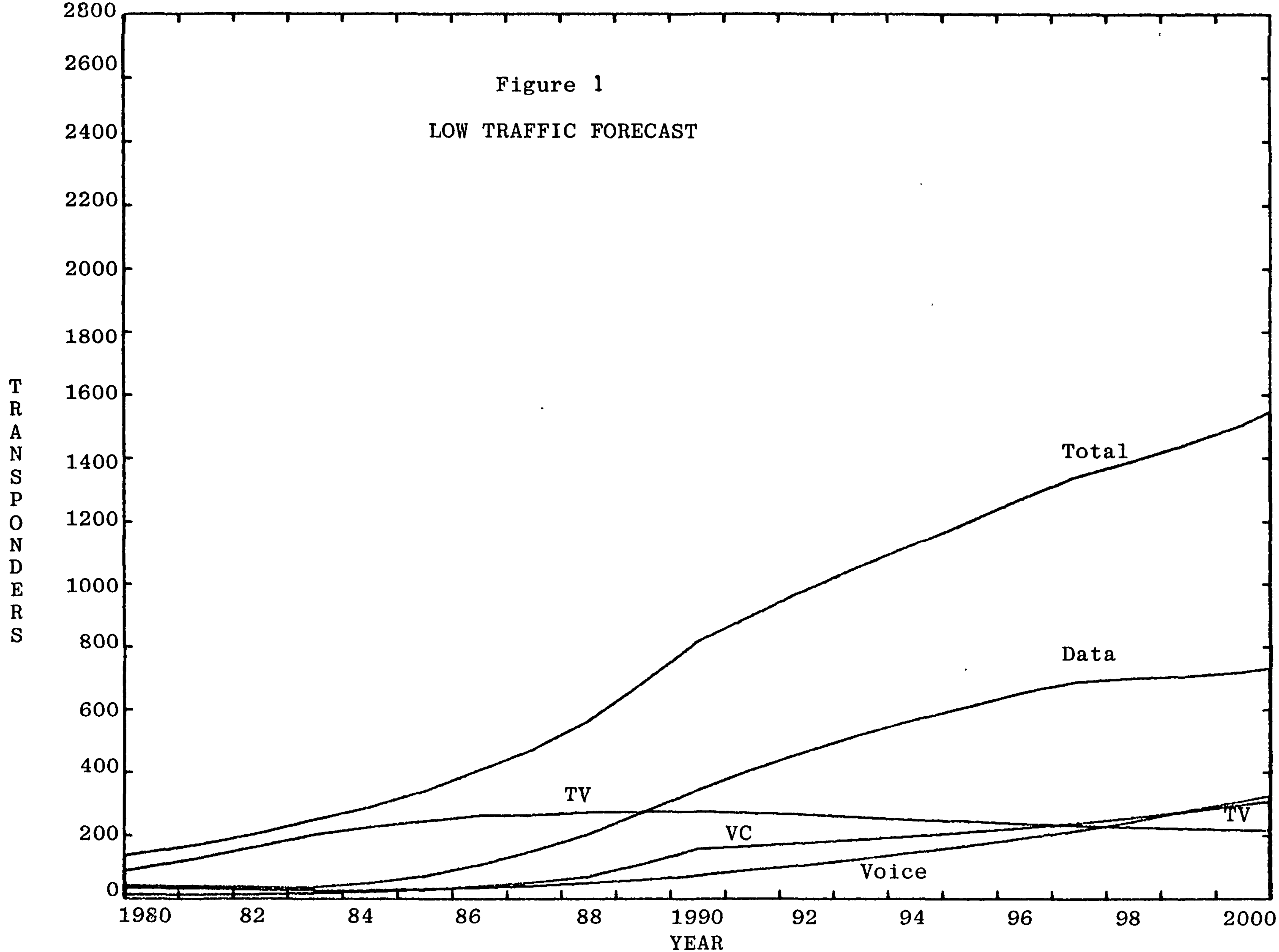


Figure 2

HIGH TRAFFIC FORECAST

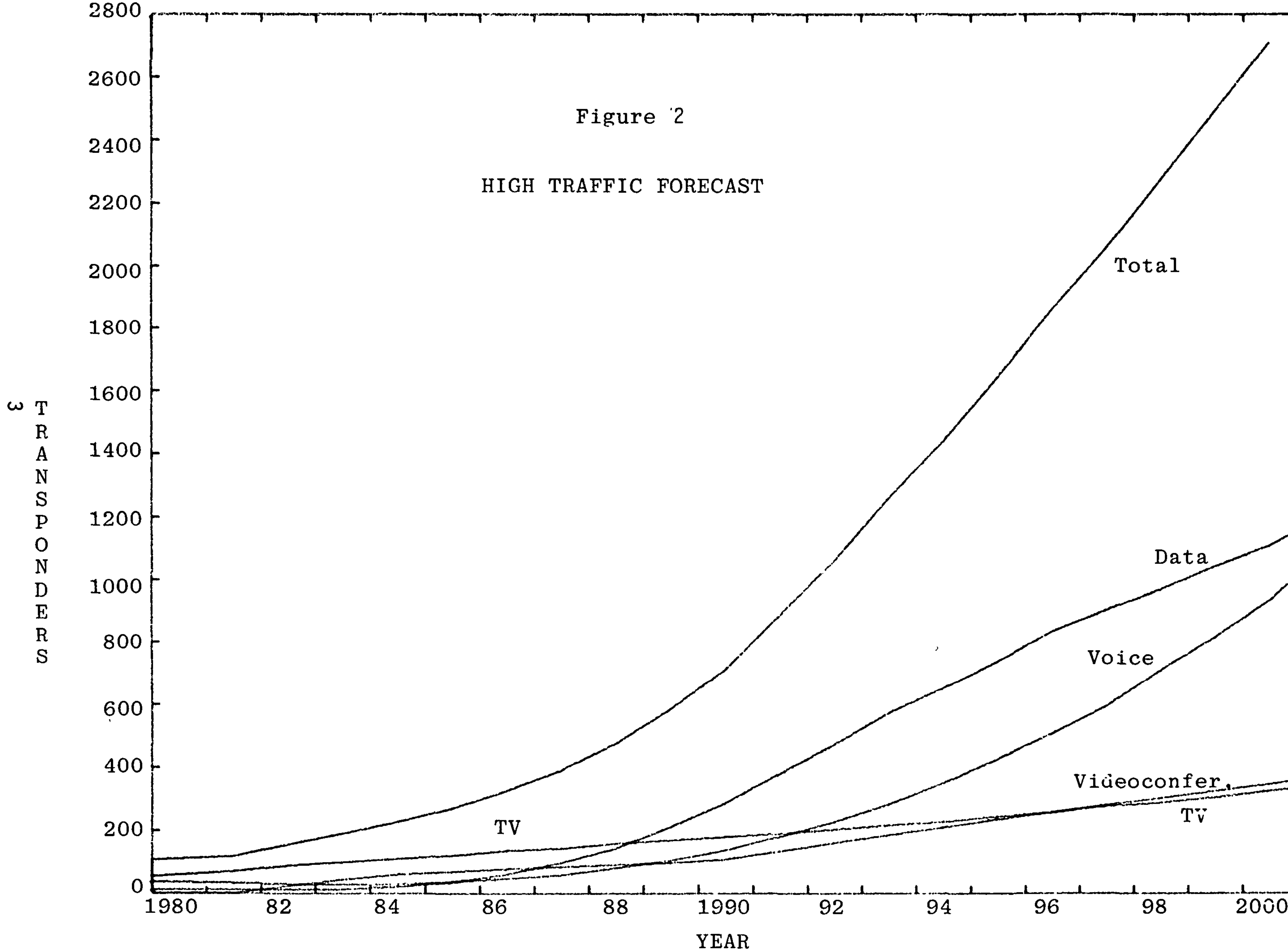


Table 1

Normalized Effects on the

Low Forecast - 1990

Stage	Voice	Data	Video Conferencing	TV
Base Forecast (satellite-addressable)	1.0	1.0	1.0	1.0
After Satellite Capture	0.21	0.37	0.90	1.0
Includes Time Zone Effects	0.144	0.546	0.84	1.0
Includes Grade-of-Service Factors	0.165	0.546	1.074	1.0
Includes Transponder Spares	0.205	0.682	1.15	1.07

2.0 Task 2

Task 2 required the formation of a model for the satellite industry. Of course, this model was primarily used to estimate the response of the industry to the traffic forecasts of Task 1.

Various factors were unknown; we made assumptions that in some cases were varied to form different scenarios. Since we implemented the model using a computer program, other variations could be readily evaluated. We deliberatly kept the number limited to avoid flooding the reader with data, much of which would be useless.

Supply and Demand

An important consideration is the availability of orbital slots at the desired frequency band or bands. We have recently seen what a great effect such a limitation can have on the plans of would-be system operators. Depending on the needs of the customer base to be addressed, there may be one band which is more desirable than others; however, if slot is not available, then the operator will be out of luck.

In Table 2 the longitude limits which we used in this study are shown together with the number of slots available at two degree spacing at each frequency band.

We have calculated the available supply (without launching any as-yet unannounced satellites) in two ways: first, using only the satellites that have been approved, and second, using all satellites for which we have information.* The figures also include random failures of transponders, but don't include-relatively recent events such as the failure of twelve transponders on SATCOM II (which is almost dead anyway). These projections are plotted in Figures 3 and 4, along with the Low and High traffic forecasts respectively.

*Note that several of the most recent group of satellites were not included. This work was done before their applications were filed.

Figure 3

SUPPLY OF KNOWN SATELLITES AND LOW TRAFFIC

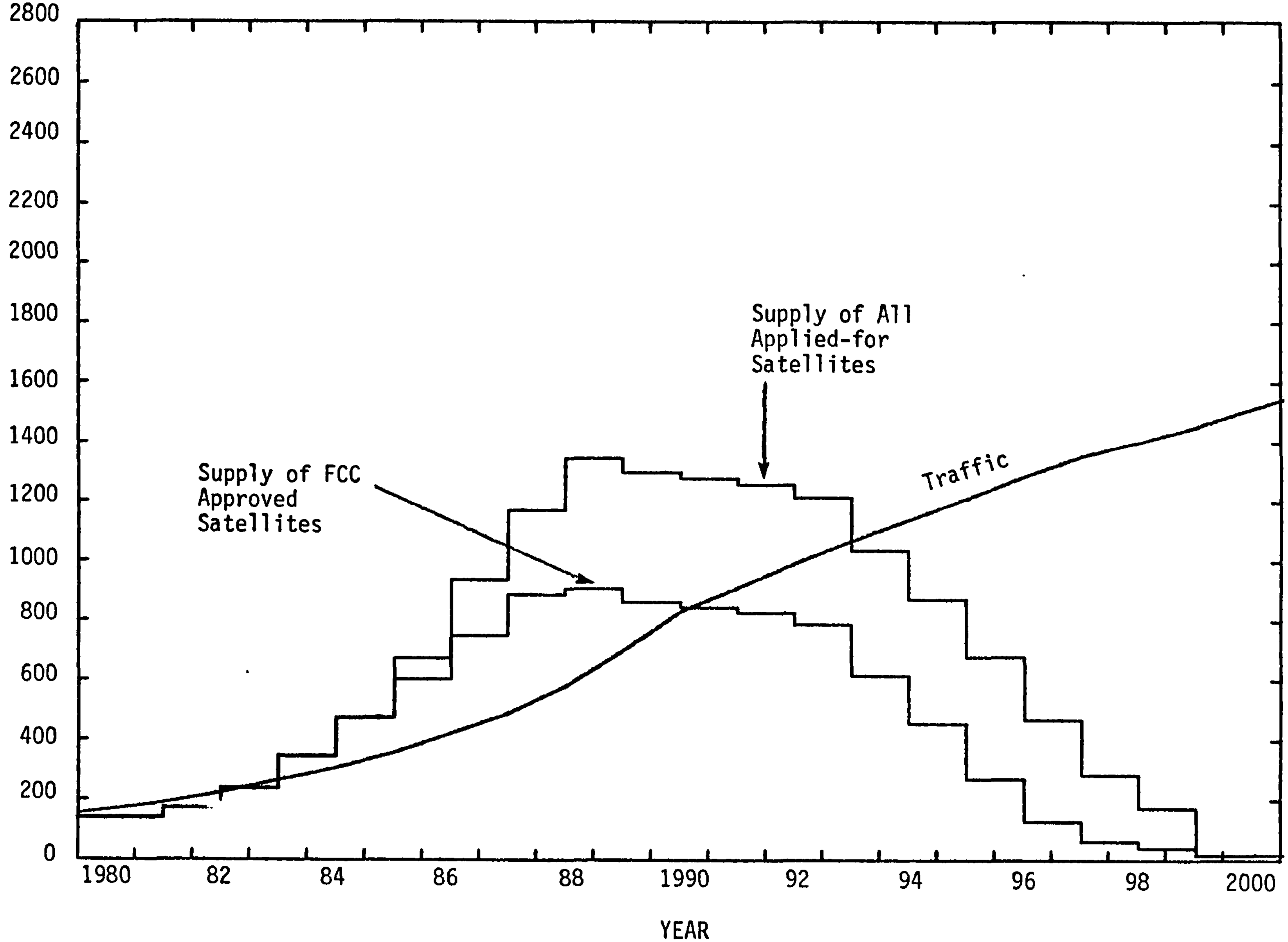


Figure 4

SUPPLY OF KNOWN SATELLITES AND HIGH TRAFFIC

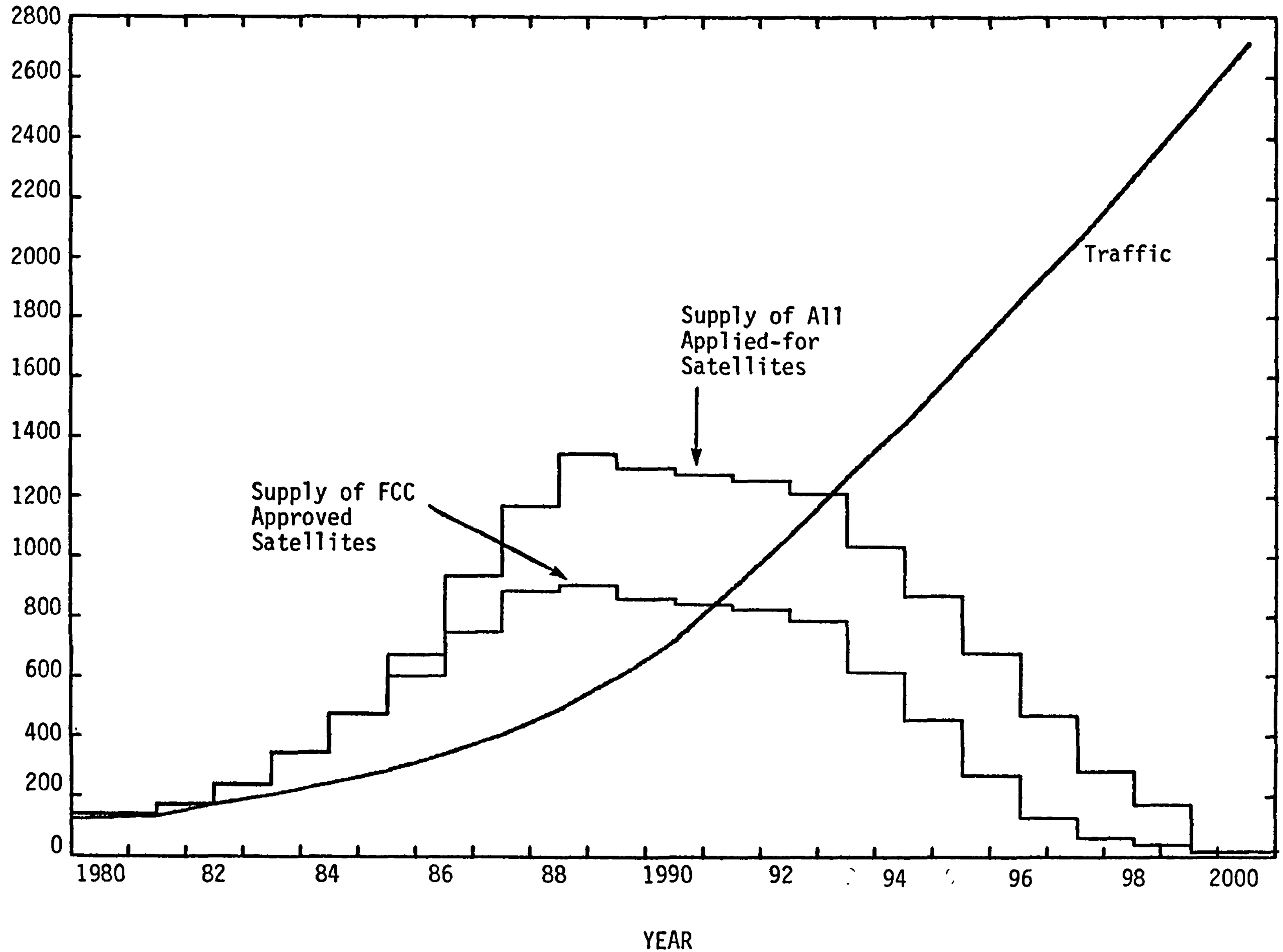


Table 2

Orbital Arc

Band	Number of Slots	Orbital Range
6/4	35*	59° - 101° 119° - 143°
14/12	34	59° - 105° 120° - 139°
30/20	23	75° - 119°

*Based on 1983 assignments, these are actually only 30 slots. The 35 figure assumes all 2° spacing.

Practical Satellite Efficiency

In constructing an actual multi-beam satellite, we would not necessarily have to provide the maximum possible capacity per beam, but could use the assumed traffic distribution to tailor the satellite to the beam loading. That is, if at saturation a given beam will only carry 2 transponders, then we only install 2 transponders for that beam. Thus, although the efficiency with which the beam pattern is used will be low, the efficiency with which the physical facilities of the satellite are used will be much higher.

This can best be illustrated by some examples. These are shown in Table 3.

Table 3

Satellite Capacity Examples

Band	C_{Net}	N	Efficiency η	Gross Capacity
C or Ku	24	1	100%	24
30/20	24	10	49%	29
C or Ku	36	18	24%	45
30/20	36	10	49%	41
C or Ku	48	27	22%	61
30/20	48	10	49%	53
C or Ku	96	96	13%	144
30/20	96	10	49%	101

Satellite Industry Scenarios

The model is traffic-driven, and includes a number of assumptions about the distribution of traffic among the various frequency bands. Because of these assumptions, we have run the model using several scenarios, varying the assumed behavior to show the sensitivity of the results. Virtually all of the scenarios converge to systems which make use of multiple-spot-beam antennas and/or the 30/20 GHz band. The specific traffic distributions and satellite constellations don't all converge, however, and the difference can provide some illustration of the effects of different constraints.

Scenario Results

Detailed results for all scenarios are too lengthy for inclusion in this Summary. Tables 4 through 6 and Figures 5 through 7 were chosen as a covering range of realistic conditions.

SUMMARY FOR
CASE #1 -- SOME DEMAND FOR EACH BAND -- NO LIMIT ON C-BAND OR KU-BAND
CAPACITY EXCEPT STRICTLY TECHNICAL AS ESTIMATED.

LOW TRAFFIC FORECAST

	FREQUENCY BAND		
	C-BAND	KU-BAND	KA-BAND
MAXIMUM SATELLITE (TRANSPONDERS):	37	37	65
YEAR LAUNCHED:	1994	1999	2000
FIRST MULTIBEAM SATELITE IN:	1994	1999	1992
GROSS CAPACITY			
1980	128	0	0
1990	672	744	0
2000	917	842	180
NET CAPACITY			
1980	128	0	0
1990	672	744	0
2000	812	831	164
AVERAGE CAPACITY			
1980	19	0	0
1990	24	22	0
2000	33	25	45

Table 4

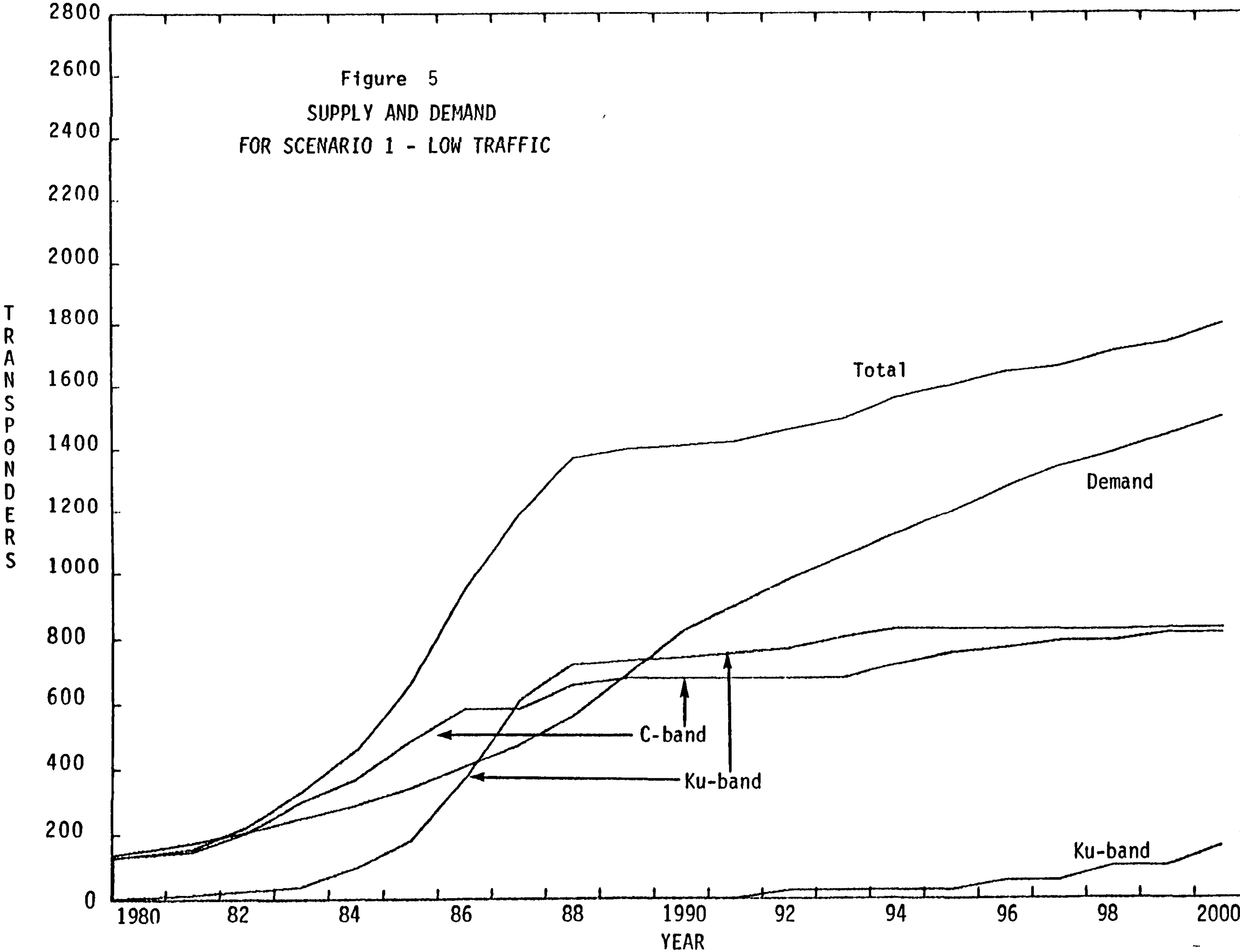


Figure 5
SUPPLY AND DEMAND
FOR SCENARIO 1 - LOW TRAFFIC

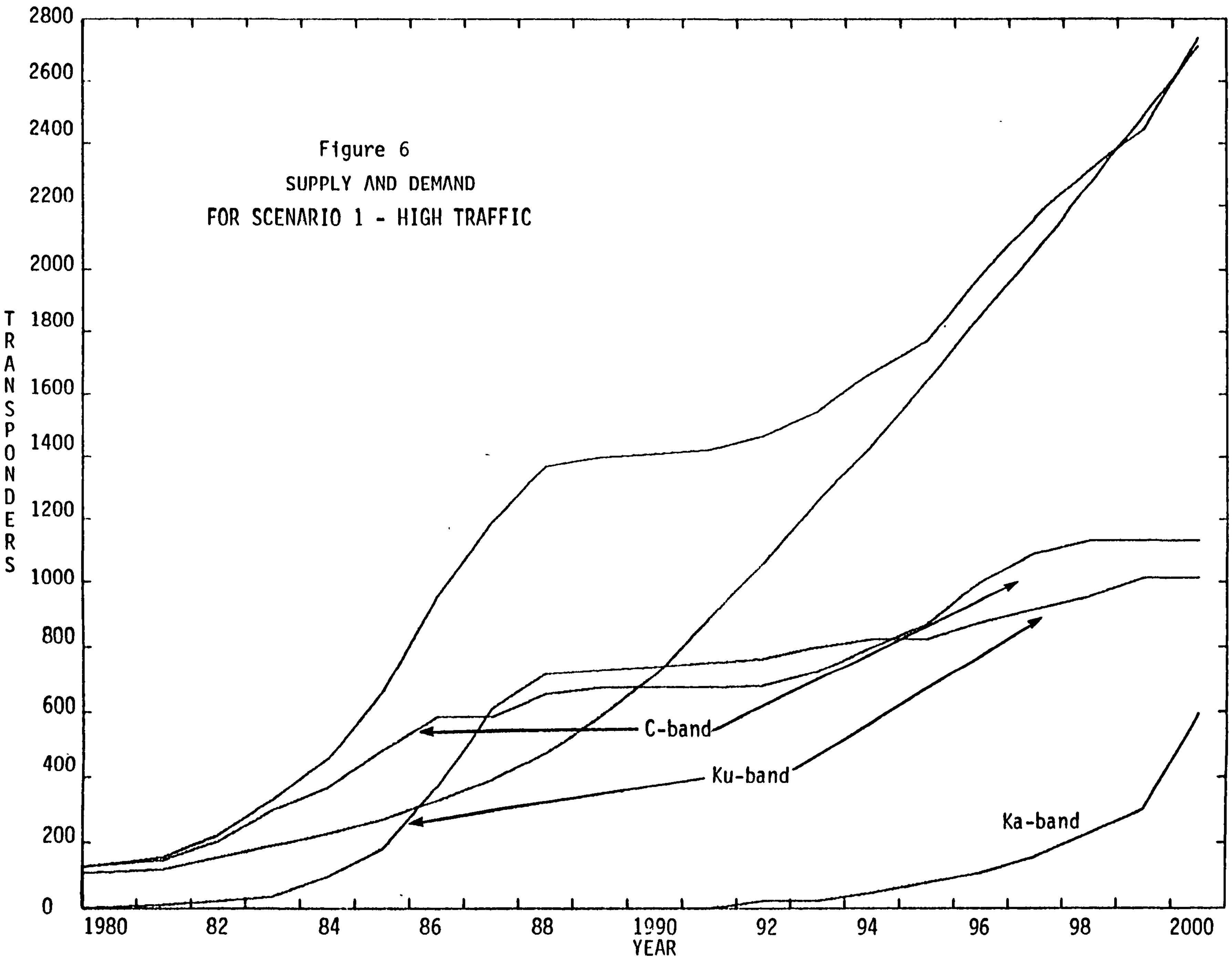
SUMMARY FOR
CASE #1 -- SOME DEMAND FOR EACH BAND -- NO LIMIT ON C-BAND OR KU-BAND CAPACITY EXCEPT STRICTLY TECHNICAL AS ESTIMATED.

HIGH TRAFFIC FORECAST

	FREQUENCY BAND		
	C-BAND	KU-BAND	KA-BAND
MAXIMUM SATELLITE (TRANSPONDERS):	58	61	84
YEAR LAUNCHED:	1996	1999	2000
FIRST MULTIBEAM SATELITE IN:	1992	1996	1992
GROSS CAPACITY			
1980	128	0	0
1990	672	744	0
2000	1329	1148	641
NET CAPACITY			
1980	128	0	0
1990	672	744	0
2000	1133	1016	595
AVERAGE CAPACITY			
1980	19	0	0
1990	24	22	0
2000	38	34	58

Table 5

Figure 6
SUPPLY AND DEMAND
FOR SCENARIO 1 - HIGH TRAFFIC



SUMMARY FOR
CASE #1C -- SOME DEMAND FOR EACH BAND -- 24 TRANSPONDER LIMIT AT C-BAND
36 TRANSPONDER LIMIT AT KU-BAND

HIGH TRAFFIC FORECAST

	FREQUENCY BAND		
	C-BAND	KU-BAND	KA-BAND
MAXIMUM SATELLITE (TRANSPONDERS):	24	45	86
YEAR LAUNCHED:	1986	1995	1998
FIRST MULTIBEAM SATELITE IN:	0	1995	1992
GROSS CAPACITY			
1980	128	0	0
1990	672	744	0
2000	840	1233	908
NET CAPACITY			
1980	128	0	0
1990	672	744	0
2000	840	1075	849
AVERAGE CAPACITY			
1980	19	0	0
1990	24	22	0
2000	24	36	65

Table 6

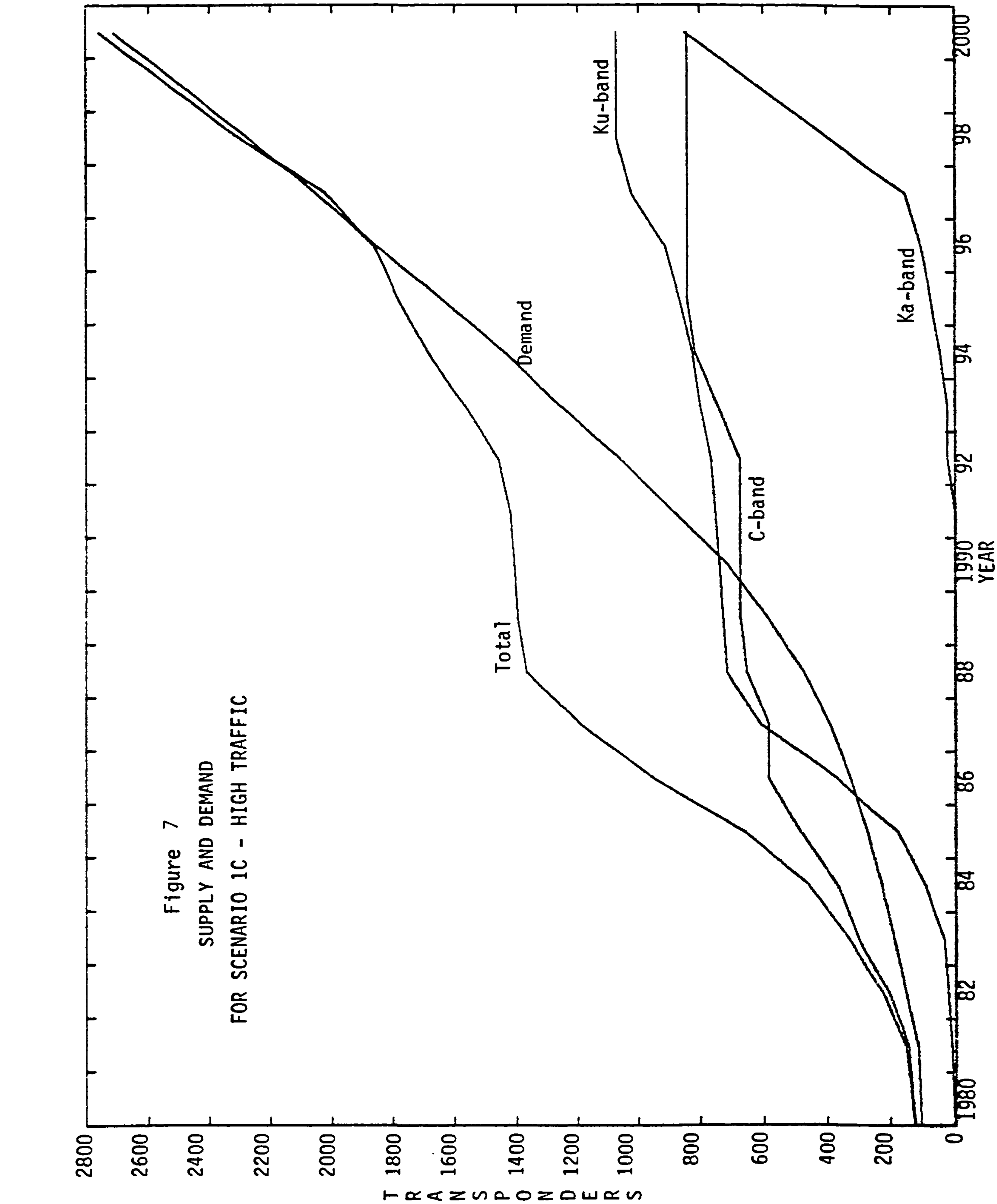


Figure 7
SUPPLY AND DEMAND
FOR SCENARIO 1C - HIGH TRAFFIC

3.0 Earth Station Forecasts

The growth of the earth station population is roughly proportional to the traffic, varying according to the kind of traffic (i.e. — CPS or trunking or TV, etc.). The number of earth stations per transponder of traffic has historically been an increasing function with time, and we expect this to continue within reasonable limits. For TVRO or very thin route stations, the practical limits are quite high or non-existant. However, for stations which carry a significant amount of traffic and require access to one or more transponders on a continuous basis, there are fairly low limits.

The earth station size mix will also vary according to traffic category. This is partly an economic decision, since a smaller earth station of less complexity and lower price will be needed to make lighter traffic economical to carry. However, the consideration of physical placement is very important for CPS services. This is especially so at Ku-band and 30/20 GHz, since these stations will be located in metropolitan areas (as well as elsewhere) and hence must be as unobtrusive as possible.

Since the various scenarios produce somewhat different distributions of traffic among the frequency bands, we estimated the earth station requirements for each one. Summary results of earth station requirements are shown in Table 7.

Table 7

Total Earth Station Estimates for the Year 2000

Scenarios	C-band	Ku-band	Ka-band
Low Traffic			
1	3,384	3,168	556
2	5,887	1,223	0
3	4,830	2,281	0
High Traffic			
1	10,180	11,460	5,837
2	13,167	9,830	4,478
3	11,492	11,498	4,487
1B	7,477	9,377	10,621
2B	7,949	8,974	9,388
3B	7,870	9,053	9,388
1C	7,477	11,953	8,047
2C	7,949	11,949	7,579
3C	7,870	12,467	7,137

4.0 Economic Analysis - Task 2

Satellite communications has developed into a rather large business, with total investment in current satellites of over $1 billion in the U.S. domestic systems alone. According to a recent article, the worldwide communications satellite market is approaching $3 billion per year, excluding ground segment. Thus it is important that we examine the effect of our postulated future satellites on the overall market, in economic terms.

The cost of satellites launched during each scenario run in Task 2 was estimated using the SAMSO cost model. Launch costs were estimated based on the weight of the satellite and the costs of known launch vehicles. All these figures were expressed in 1983 dollars to provide a common standard.

We also estimated costs for the example earth station configurations that we used, using data of our own, plus information developed by Western Union.

Table 8 shows the total cumulative costs of meeting the earth station requirements postulated in Section 11. We have not included costs for networking of trunk and shared CPS earth stations in these costs.

Space segment costs are also shown. Investments for known satellites (i.e. - not generated by the program) are not included.

Table 8

Cumulative Investment Costs

for Scenario Runs

(millions of 1984 dollars)

Scenario	Space Segment	Ground Segment
Low Traffic		
1	7,545	4,797
2	8,072	4,576
3	7,469	4,682
High Traffic		
1	10,528	14,270
2	11,239	14,150
3	10,340	14,340
1B	13,143	13,868
2B	12,287	13,337
3B	12,287	13,330
1C	11,506	14,203
2C	11,500	14,264
3C	10,330	14,315

5.0 Summary and Conslusions

This report has covered a rather wide range of topics relating to satellite communications in the U.S. To one extent or another, of course, the various results depend on one another and on assumptions that we made during the course of the study. Some of these assumptions are more arguable than others, for instance, our selection of data rate for a CPS transponder, and our speculations about the courses of action of the several long-haul carriers using satellite transmission. Given the traffic forecasts that we began with, however, we are of the opinion that no reasonable variation of assumptions would change the magnitude of either the high or low traffic forecast by more than a factor of about two.

Conclusions from the Scenarios

With the currently-mandated 2 degree spacing at C-band and Ku-band, the scenario runs clearly indicate that the average capacity needed at each band is relatively modest for the Low traffic cases, and feasible, but rather advanced for the High traffic. It's worth noting that the 2B and 3B scenarios used every slot, even at 30/20 GHz. However, it would be instructive to investigate different ways in which this capacity might be provided. The scenario runs present one way, but not the only way, in which satellites might be launched to satisfy demand. The various possibilities might be loosely classified as: Multiple Small Satellites (as in the scenarios); Multiple Hybrids of modest specific capacity; Rapid Transition to Large Satellites.

The Role of Satellites in the Overall Communications Structure

Satellites are, and will remain, ideally suited for broadcast applications. It is hard to conceive of a development in terrestrial communications technology that would undermine this advantage, at least in the United States. There are a number of countries whose physical extent is limited enough that it is actually less expensive for them to install a terrestrial broadcast system (for TV and radio) than to launch a satellite or even share a satellite for DBS purposes. However, our large land area and common interests, along with our seemingly inexhaustible appetite for programming, will ensure a continuing role for satellites in broadcast. But what of point-to-point communications?

In point-to-point communications, satellites have been used mainly to enable the "great leap" whereby new communications modes are offered, or conventional modes expanded or opened to competition. This leap is generally necessary because terrestrial communications systems suffer from a "critical mass" or "critical density" syndrome. Until and unless the density of users becomes relatively high, the distance-sensitivity of terrestial links makes the cost of the system exorbitant. An added user is likely to cause the system to incur a very high added cost. Once the density of users is high enough, the incremental cost per user drops and continues to drop as the user base expands. In a satellite system, different rules prevail.

An additional satellite user always incurs (roughly) the same incremental cost no matter where he is located. The network can therefore add service points and grow without penalizing any particular users with high costs. This feature makes satellites ideal for new systems or modes of communications, where users are initially few and far between. This is why satellites have been used for trans-oceanic communications, greatly expanding the available facilities and improving quality, and for new services such as wideband data communications and videoconferencing.

As such services become better established, and the density of users increases, terrestrial technologies begin to encroach. This process can readily be seen at work today. It is our view that several factors will keep satellites viable for many years. Among these are: the continuing existance of remote users, the competitive environment in the U.S., and the economic advantage of existing facilities.

Footnote: The Year 2000

The year 2000 has become something of a touchstone for long-range planning. Indeed, one sometimes gets the impression that there is a veil drawn across time which prevents us from seeing beyond that date. The usual short-term focus of commercial firms, for whom five years is "long-range", probably causes some of the reluctance to look beyond the end of the century.

However, it's our opinion that some interesting things will just be beginning to happen by the year 2000, in communications and in space generally. We are already in a position where the firm plans of communications carriers today will affect the actual events of the early 1990s. This leaves relatively little scope for action if we limit our future vision to the year 2000. To alter the course of events requires either enormous power acting in a short time, or a long time for moderate influence to be effective. We respectfully note that we (and NASA) are more likely to be in the latter position than the former. Therefore, we need to look further and identify decision points that are within the range of our influence.